Art. XVI.—*The Petrology of certain Victorian Granites.*

By EVELYN G. HOGG, M.A.,

Acting Professor of Mathematics, University of Tasmania.

[Read before the Australasian Association for the Advancement of Science, Melbourne, 12th January, 1900.]

The principal sources of information with respect to the distribution of granite in Victoria are the essay of Mr. A. R. C. Selwyn, published in connection with the catalogue of the Victorian Exhibition of 1866; and the text-book on the Geology and Physical Geography of Victoria of Mr. R. A. F. Murray, published in 1887. Brief macroscopic descriptions of Victorian granites may be found in the "Catalogue of the Rock and Mineral specimens in the Technological Museum, Melbourne," edited by the late J. Cosmo Newbery.

Up to the present time little attention appears to have been paid to the petrology of the granites of Victoria. Notes on the subject are scattered through the writings of Mr. A. W. Howitt, and an interesting paper on the granite of Cape Woollomai, by Mr. James Stirling, Government Geologist, occurs in the Progress Report of the Mines Department, 1899, vol. x., p. 107.

The author of the present paper has had during the past few years many opportunities of collecting granites in Victoria, and he has recently received from Mr. A. E. Kitson, F.G.S., of the Mines Department, through the courtesy of Mr. Stirling, a few specimens of granitic rocks from some of the more inaccessible parts of Victoria.

In the following paper the petrological characters of these granites are briefly described:—The terminology of rocks of granitic type is a matter of discussion. In the present paper normal granite is defined as a holocrystalline rock composed of quartz, biotite and two felspars, the triclinic felspar being subsidiary to the monoclinic. Variation from the normal form may, among other ways, take place by a change in the relative propor-

tions of monoclinic and triclinic felspars present until a point is reached in which the triclinic felspar is clearly the dominant one.

To this extreme type there is no difficulty in assigning the term granitite. Between these limits, however, lies a large range of rocks in which the relative proportions of the felspars may vary greatly, and it is to be desired that a name existed to apply to these intermediate rocks. The name which might well have been applied to them is granitel; this term, however, has been secured for rocks of the aplite type in which mica is either absent or present only in small quantities. The term "granitel" has not as yet received any general adoption, and it is worth considering whether the original signification of the word might not be changed, and the term in future be applied to rocks of granitic type in which neither felspar can be said to predominate over the other. In the present paper, however, I have not adopted this term, and have preferred to classify the rocks in question on the old well-established description of a true granite. So long as the rock is one in which the monoclinic felspar is clearly the important one the rock is a granite, but when the triclinic felspar ceases to be subsidiary to the monoclinic felspar I have adopted the term granitite. In other words, I suggest the extension of the word "granitite" to include all holocrystalline quartz—biotite—rocks in which a monoclinic felspar is not the dominant one, thus bridging over the gap between the granites and the rocks formerly styled granitites. To conclude the question of nomenclature, a normal granite with muscovite added is, adopting the French term, a granulite; a normal granite with hornblende is a syenite, granitite with hornblende is a diorite, while the somewhat rare case of a granitite with muscovite is called a muscovite-granitite.

Examination in the field shows that in a small area rocks of granitic type may vary greatly in macroscopic appearance even when no contact or regional metamorphism may have taken place, and it may therefore happen that to describe fully the granite of a particular district it would be necessary to prepare a large number of slides. This course the author has not been able always to adopt, owing often to the impossibility, in the absence of recently-worked quarries, of obtaining specimens suitable for slicing. Even fresh-quarried granites often are so brittle that a

sufficiently thin slide cannot be obtained without reducing the rock to a very fragmentary condition. The decomposition which the felspars have in most cases undergone often makes the exact determination of the plagioclase felspars quite impossible. So far as possible specimens typical of the locality under examination have been sliced and are described in the following paper.

The extent and boundaries of the granite outcrops are not given as information on this point, can be more easily and accurately obtained from the geological maps of Victoria, issued by the Department of Mines, and only brief reference is made to the other field relations.

Harcourt.—A granitite showing a white felspar, greenish quartz and black mica. The twinning planes of the triclinic felspar are visible to the naked eye. Under the microscope it is seen that monoclinic and triclinic felspars are fairly equally distributed through the slide. The triclinic felspar has the more perfect terminal faces, often shows zonal structure and occurs as an inclusion in the monoclinic felspar. Measurements suggest that the triclinic felspar is oligoclase. The orthoclase felspar shows Carlsbad twinning and intergrowth with a triclinic felspar, probably albite. Apatite occurs in slender prisms and as grains included in the biotite. This granitite is intrusive into the Lower Silurian rocks, the latter being, according to Mr. E. J. Dunn, F.G.S., altered in the neighbourhood of Bendigo for a distance of 25 chains from the granitite. Similar contact metamorphism has not yet been noted in the deepest mines of the Bendigo field.

Traawool, 7 miles E. of Tallarook.—A coarse-grained granitite, rich in quartz, and showing a white felspar and biotite, the latter mineral often in perfect hexagonal crystals. Under the microscope it is seen that the triclinic felspar is as well represented as the monoclinic, that it has better crystal definition and that it occurs as an inclusion in the monoclinic felspar. Both felspars are much decomposed, but the triclinic felspar shows the less alteration of the two. A small amount of apatite is present; muscovite occurs in minute clusters and is probably a secondary product.

Millpark, N. of Preston.—A fine-grained granitite showing a white felspar, quartz, and biotite. In the thin slide triclinic

felspar, which is apparently oligoclase, is represented in larger quantity than the monoclinic; the triclinic crystals have good terminal faces, while the orthoclase rarely has. Among the accessory minerals are zircon and apatite. The order of crystallization appears to have been—accessory minerals, mica, oligoclase, orthoclase, and quartz. The latter mineral is free from inclusions. This granitite is intrusive into the Upper Silurian Rocks.

Harkaway.—A fine-grained syenite showing a white felspar, biotite, hornblende, and much quartz. Monoclinic felspar appears under the microscope both in larger crystals and greater quantity than the triclinic felspar; the latter has the more perfect crystal edges of the two, and is a frequent inclusion in the monoclinic felspar. This phomenon of inclusion and the manner in which the orthoclase is moulded on the plagioclase show that the latter mineral was the first to crystallize. Hornblende is present in small quantity; it is somewhat bleached in colour, and is only faintly pleochroic; the crystals have ill-defined terminal faces. Biotite is often altered to chlorite. A small amount of apatite is present.

This rock is in many places traversed by fine-grained veins, which weather out from the softer main mass. Under the microscope it is seen to be mainly composed of quartz grains, through which are distributed ill-bounded crystals of microcline, a triclinic felspar—probably oligoclase—grains of a monoclinic felspar and a minute quantity of mica. There is no trace of hornblende. The material forming these veins appears to occupy cracks formed in the main mass by contraction under cooling, and to be a later emission from the central magma. Its constitution seems to support the view that when more than one emission takes place from the same central magma, the later emissions are more acid in character than the earlier ones.

Warburton, six miles east of township, near tin-mine.—A coarse-grained granite with large pink felspars, blebs of quartz and a small quantity of mica. Under the microscope it is seen that the prevailing felspar is a somewhat cloudy orthoclase. The triclinic felspar is oligoclase, it occurs as a frequent inclusion in the orthoclase, when it is sometimes bounded by a thin layer of quartz. There are indications in one slide that a partial crystallization of the quartz had accompanied that of the orthoclase. Apatite is sparingly represented.

Warburton, near old township.—A fine-grained granite rich in biotite. Orthoclase somewhat destitute of crystal boundaries occurs in larger plates and greater quantity than the triclinic which appears to be an acid-oligoclase. The latter shows good zonal structure and is twinned according to both albite and pericline laws. It has well-marked crystal edges except when it occurs as an inclusion in the orthoclase, in those cases the edges are often eroded. Zircon and apatite are rather frequent, quartz is free from inclusions except mica.

Somerton.—Southern end of outcrop, about 3½ miles N.N.W. of Broadmeadows Station.—A medium-grained granitite with white felspar, bottle green quartz and biotite. In the slides it is apparent that the monoclinic felspar is subsidiary to the triclinic variety. The latter has good crystal boundaries and has resisted alteration better than the orthoclase. Quartz is well represented, and the rock is very rich in apatite. Biotite is largely altered to chlorite. A small amount of muscovite is present, it appears as an alteration product of orthoclase.

Frankston.—On the eastern side of Port Philip Bay are three isolated granitic areas, Frankston, Mount Martha and Dromana. It is possible that at one time they formed a continuous chain. At Dromana the hills attain, at Arthur's Seat, a height of 970 feet, and at Mount Martha and Mount Eliza close on 600 feet. The isolated areas are separated on the shore line by tertiary beds, and are bounded easterly by Upper Silurian rocks into which they have intruded. The rock from Frankston is a medium-grained granitite showing a pink felspar, quartz and biotite. Orthoclase and plagioclase felspar are about equally represented in the slide, the biotite and quartz are normal. No traces of apatite, zircon or other accessory minerals could be found.

Mount Martha. — Watson's Quarry. A medium-grained syenite showing white felspar, clear quartz, biotite and long prismatic crystals of hornblende. The dominant felspar is monoclinic, it contains as inclusions triclinic felspars with rounded edges. The triclinic felspar is an acid oligoclase with a maximum extinction angle, measured from the twin line, of about 10°. Hornblende is present in moderate quantity; the terminal faces of prismatic sections are for the most part wanting; the pleochroism

is somewhat intense, it appears to be entirely free from inclusions. The quartz and biotite present no features of interest. A small quantity of apatite is shown in the slides.

A vein about one inch thick traverses the quarry, it is a fine-grained rock which appears, in the thin slide, to be composed of grains of quartz on which a monoclinic felspar is moulded. It contains a small amount of mica, but there is no trace of hornblende. It is essentially an acid rock.

A feature of interest in the quarry is a large sub-angular block of quartzite contained in the granite. It appears identical in microscopic character with metamorphosed rock occurring near the junction of the syenite and silurian beds.

Mount Martha Point.—The main rock here does not differ from the syenite of Watson's quarry except that the hornblende is less frequently present. It is traversed by thin veins similar to the one above described. It possesses some interest however in the occurrence of (1) a vein of pegmatite, (2) dark ovoid-shaped basic secretions.

The pegmatite vein appears macroscopically to be composed of felspar and quartz only, but the microscope shows the presence of a minute quantity of biotite. The felspar appears to be exclusively orthoclase, and there is considerable intergrowth of quartz and felspar. Hornblende is absent.

The basic secretions occur in small ovoid masses rarely more than a few feet in diameter. The normal form is a fine-grained dark rock in which biotite is the prevailing mineral, variation from this type arises from the occurrence in the rock of porphyritic masses of pink felspar. Examined microscopically, the rock is seen to be a crystalline granular aggregate of mica, quartz and orthoclase, with a small amount of hornblende. [One slide failed to yield any traces of hornblende]. The almost entire absence of a triclinic felspar is noticeable. Sphene and apatite are both present in small quantities.

Dromana.—Quarry on Arthur's Seat.—A fine-grained syenite in which a pink felspar, quartz and mica are visible. In the thin slide the monoclinic felspar is seen to preponderate over the triclinic, it is frequently twinned according to the Carlsbad law. The triclinic felspar is occasionally an inclusion in the monoclinic. Hyp-idiomorphic crystals of a light green hornblende showing

marked pleochroism are scattered through the slide. A somewhat fibrous biotite, often bent and contorted, is sparingly distributed. Apatite occurs in prisms and grains, it is a frequent inclusion in hornblende and biotite.

Dromana.—Coast near township.—The main rock mass is here too weathered to furnish satisfactory slides. It is, however, penetrated by veins and contains ovoid patches very similar in appearance to those occurring at Mount Martha and previously described. Under the microscope it is seen that in the basic secretion hornblende is the prevailing mineral, there is a fair amount of mica, and both monoclinic and triclinic felspars appear. Sphene and apatite both occur and there are traces of quartz. As at Mount Martha, the veins are poor in mica and entirely without hornblende.

Cobungra High Plains.—A medium-grained granite with a pink felspar, bottle green quartz and biotite in small clusters. In this rock the prevailing felspar is a monoclinic which contains many rounded fragments of triclinic felspar. Both felspars are much altered and clouded. A striking feature of the rock is the abundance of sphene and the occurrence of ilmenite in characteristic cross-hatched sections. Apatite is also present.

Watts River.—Aqueduct, near Healesville.—A medium-grained granitite showing white felspar, greenish quartz and biotite. Careful examination of the slide shows that the triclinic felspar occurs more largely than the monoclinic, it has better crystal boundaries and has suffered less alteration. Measurements of the triclinic felspar give a maximum extinction angle of 16°, thus leaving it in doubt whether the felspar is an albite or oligoclase-andesine. Biotite is well represented, it is frequently altered to chlorite. Apatite is present. Calcite and muscovite appear as secondary products.

Little Snowy Creek.—Above Tallandoon, near Tallangatta, Mitta Mitta River.—A coarse-grained greisen with cassiterite. The rock is almost entirely composed of quartz and muscovite. Sphene is present in fair quantity. The quartz grains are charged with opaque dust which is arranged along intersecting lines and curves.

Mount Hotham to Victoria River, Cobungra.—A somewhat fine-grained granite rich in quartz and biotite with white felspar.

It is with some diffidence I class this as a granite, as owing to the decomposition of the slide it is difficult to determine whether the monoclinic felspar or the triclinic felspar is the preponderating one. Biotite is somewhat bleached and contains minute zircons. Quartz is free from inclusions. Apatite is sparingly represented.

For the last four specimens described I am indebted to Mr. A. E. Kitson, F.G.S., of the Mines Department.

Yackandandah.—An account of the field relations of the Yackandandah and Beechworth granitic areas is given in Progress Report, No. 2, of the Department of Mines, pp. 75, etc. The specimens sliced from this locality were all taken from the bed of the creek about a mile below the township. Though the quarries near the township used for building purposes have only been closed for about 10 years it was impossible to find there any specimens which weathering had not rendered quite unfit for slicing. The rock is fairly constant in appearance over considerable areas near the township. Large milk-white crystals of felspar embedded in a matrix of quartz and biotite is the characteristic form, the texture is for the most part coarse. Close inspection shows that mica is a frequent inclusion in the felspar. Scattered through the main mass are frequent patches of dark closed-grained material which is harder and more difficult to fracture than the surrounding rock. These patches are of small dimensions and the line of demarcation between them and the surrounding rock is well marked. Biotite, quartz and triclinic felspar can be detected in them by the naked eye.

The main rock mass at Yackandandah is an interesting example of the occurrence within a short distance of each other of both granite and granitite. In some slides the monoclinic, in others the triclinic, felspar is the leading one. The triclinic felspar is an acid oligoclase with a maximum extinction angle measured from the twin line of about 10°. It occurs in two generations, being found not only as an inclusion in the monoclinic variety but also in the triclinic. There is a small amount of microcline present in the rock. Quartz and biotite are normal. Sphene and apatite occur in most of the slides.

The basic secretions under the microscope show a crystalline-granular structure in which biotite and mica are the prevailing

minerals, the triclinic felspar which is oligoclase is almost destitute of crystal edges. Sphene and apatite are well represented and there are traces of zircon. A feature in these secretions is the colourless needles which penetrate the quartz, they are possibly rutile. Monoclinic felspar is present in very small quantity. Most of the slides show a small amount of epidote, which appears always to be associated with the biotite. The quartz shows a fair number of cavities, mostly cylindrical in shape, in which enclosed crystals may be seen. Liquid cavities are rare.

Beechworth (1) Quarry, near Powder Magazine.—A coarse-grained granite, showing a pink felspar, dark green quartz and a little biotite. The prevailing felspar is orthoclase, it contains inclusions of mica and triclinic felspar and in it perthitic structure is well displayed. Quartz is free from inclusions. Apatite and muscovite are present in small quantities.

(2) Quarry on creek above town.—This rock does not differ microscopically from the one last described except that the felspars are in a better state of preservation, biotite is present in greater quantity and muscovite is absent.

(3) Quarry behind Jail.—A medium-grained granite, showing pink and white felspars, bottle-green quartz and a small amount of mica. This rock is similar to the ones previously described from Beechworth except that the triclinic felspar plays a more important part, it is, however, subsidiary to the monoclinic. Both felspars appear to have been largely moulded on the quartz, the triclinic felspar occurs as sub-angular fragments included in the monoclinic. Apatite and zircon are sparingly represented as inclusions in biotite.

(4) Road to Wooragee, about half-a-mile from Beechworth.—A coarse-grained granite, showing a pink felspar, bottle green quartz, and a very small amount of biotite. The felspar present is almost entirely orthoclase, triclinic felspar being quite subsidiary. The triclinic felspar is occasionally included in the monoclinic. There are traces of muscovite, but apatite appears to be absent. Owing to the feeble development of mica, this rock verges on an aplite.

(5) Dyke through Rocky Mountain Gold Mining Company.—Macroscopically this rock is very similar to the specimen

described from the quarry behind the Beechworth Jail. Under the microscope it appears to be somewhat richer in quartz, the relative proportions of the felspars present is about the same, the triclinic felspar occurs as an inclusion in the monoclinic, it has undergone too much alteration to admit of any determination of its character.

Gabo Island.—My specimens from this locality are due to Professor David, of Sydney University, and to Messrs. Chambers and Clutten, Melbourne. This rock has been described in Selwyn's Catalogue of Rock Specimens and Mineral in the National Museum (1868) as a syenitic granite, consisting of red felspar, quartz and hornblende. This description appears to have been copied by Murray in his Geology and Physical Geography of Victoria (1887), and in the Catalogue of the Rocks of Victoria, in the Technological and Industrial Museum, Melbourne (1894), similar language is employed of this rock. The specimens obtained by me from Professor David did not satisfy this description, as biotite was evidently a constituent while hornblende was not. Under the microscope the sections showed much alteration, the felspars being very clouded, while the biotite was largely altered to epidote. In some cases magnetite had separated out in grains from the mica, with the result that the mica had a somewhat bleached appearance, while the intensity of its pleochroism was reduced. In addition to the epidote associated with biotite were other clusters of epidote grains; it is possible that this epidote occurs as an alteration product of hornblende. If such is the case hornblende was originally present in the rock only in small quantity. The monoclinic felspar is the predominant one. Quartz is fairly free from inclusions. Apatite is in considerable quantity, and there are traces of zircons. The specimens obtained from Messrs. Chambers and Clutten approximate in appearance the rock described by Selwyn, but biotite is present in addition to hornblende. In the thin section green hornblende shows moderate pleochroism; prismatic sections are wanting in terminal faces, good cross sections with characteristic cleavages occur. There is some alteration to epidote visible in both the hornblende and the biotite. As regards the felspars, quartz and accessory minerals, this rock is very similar to the one previously described. This variation in

its constituents in specimens taken from adjoining localities is in accordance with observations made in other parts of Victoria. The rock should be classed as a syenite.

The specimens of Victorian granitic rocks examined in this paper direct attention to the following points :—

1. The relatively large occurrence in these rocks of plagioclase felspar.
2. The plagioclase felspar sometimes occurs in two generations, has better crystal definition than the orthoclase, and has almost always preceded orthoclase in the order of crystallization.
3. The persistent occurrence of apatite as an accessory mineral in both granites and granitites.
4. The acid nature of granitic veins, and the frequent occurrence of basic secretions.